REMARKS

Claims 1-12, 16-19 and 21-24 are pending in the above-referenced patent application. All of the claims were rejected. Claims 1-12, 16-19 and 21-23 were rejected under 35 USC 112, second paragraph, because the Patent Office states that in regards to Claim 1: (1) the distinction between "algebraic form" and "geometric form" is not clear, (2) the definitions for "Tolerance Map" are not clear, (3) the term tolerance "submaps" is not defined, and (4) optimizing allocation of tolerances is not defined. Dependent Claims 2-12, 16-190 and 21-23 were rejected for the same reasons as Claim 1. Claim 1 was rejected under 35 USC 102(b) as being anticipated by USPN. 5,586,052 to Iannuzzi et al. (hereinafter "Iannuzzi"). Claim 24 was rejected under 35 USC 103(a) as being unpatenable over commercial software in view of Maxey (AutoCAD).

In this Reply, Claims 1, 6 and 10 have been amended to further clarify certain limitations therein, and new Claims 25-28 have been added. Claims 9 has been amended to correct typographical errors. No new matter has been added.

Claim Rejections Under 35 U.S.C. 112

It is respectfully submitted that the terms: Tolerance Map, algebraic form, geometric form, submaps and optimization are properly described in the specification. The following summarizes the definitions of, and the relationship

between, those term for the benefit of the Patent Office (see also, specification, for example, page 1, lines 21-23; page 10, lines 5-8; page 24, lines 11-13; and page 49, lines 15-20; etc.).

In regards to Tolerance Maps, in general, a tolerance specifies the range of imperfections in size and shape that can be permitted for an object, such as a part, to be acceptable when in use. A tolerance zone is a tolerance term that represents the physical space in which all points of a feature can exist in relation to the basic size of the object. Tolerance analysis involves accumulation of error when imperfect parts are put together (i.e., stackup problem). A primary function of Tolerance Maps (T-map) according to the present invention is to determine accumulation of error in the stackup. A Tolerance Map comprises a hypothetical volume of points that describes the acceptable positions of a surface of the object. In one example, the Tolerance Map is a convex volume whose shape depends on the tolerance type and whose size depends on the tolerance values. As such, a tolerance zone relates to the physical part, wherein the physical part can vary anywhere within the zone, and a Tolerance Map is the equivalent representation of the tolerance zone in the hypothetical volume (space).

In regards to geometric and algebraic forms, in general a model can have a geometric form or an algebraic form. For example, according to the present invention, local models take two alternative forms: an algebraic form and a geometric form. The algebraic form provides the equations needed by statistical

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tolerance analysis packages to analyze sensitivities, percent contribution, acceptance rates, etc. The geometric form provides a visual representation of the Tolerance Map. As such, each tolerance zone for each geometric feature of the object can be represented by a Tolerance Map stored in the computer. The Tolerance Map can be used: (i) to represent geometric tolerances for lines with as much ease as it represents conventional tolerances and (ii) be decomposed into regions that are allocated to different geometric tolerances. Therefore, the Tolerance Map is the geometric form, and a corresponding algebraic form (representation) can be provided for any of the points in the Tolerance Map.

Given two imperfect mechanical parts, according to the present invention, the individual Tolerance Maps of the two parts are used to determine how much error accumulates when the parts are put together (i.e., stackup). Tolerance Maps represent the entire population of imperfections in parts that are possible with a given set of specifications. Every point in a Tolerance Map represents a geometry, wherein the Tolerance Map is a mapping of physical space into the hypothetical space. As such, each part analyzed and a corresponding Tolerance Map is created that indicates all of the potential imperfections that are tolerated by the design specification. Then, when the two parts are put together (stackup), their Tolerance Maps are combined (e.g., using the Minkowski sum) to generate a new Tolerance Map (i.e., the accumulation Tolerance Map) which is the accumulation of the imperfections of the two parts. Tolerance Maps provide a graphical way of visualizing tolerances and imperfections.

In regards to submaps, as noted, Tolerance Maps provide appropriate maps for each type of geometric variation. If there are multiple variations specified on the same feature, then there are sub-Tolerance Maps (or submaps) in each Tolerance Map. This is because there are tolerance zones floating inside other tolerance zones (sub-zone). Submaps correspond to subzones. An example is a smaller limit on orientation variation (sub-zone) within a positional variation (tolerance-zone). Other examples are the orientation submap and form submap, both of which fall within the Tolerance Map for size.

In regards to optimizing allocation of tolerances, an example is selecting tolerances on objects in a way to minimize the unused volume when a double pyramid Tolerance-Map is fitted inside a double cone Tolerance-Map. One skilled in the art would know how to apply optimization to that problem to match the two volumes as closely as possible to provide the most allowance. By minimizing the unused volume, the tolerances are selected to maximize the acceptable variations of each feature and yet have an assembly (a stackup) that still functions acceptably. This procedure for minimization is a way to advise designers on how to specify objects so that their manufacture will potentially cost less.

In regards to accumulation maps and functional maps, the former is the accumulation of individual Tolerance Maps and the latter is obtained directly for a

single feature. Both are Tolerance Maps in which the tolerances are selected such that any accumulation map is inside its corresponding functional map. An example is the accumulation map for a group of parts, bearings, etc. that, when assembled, would fit into a machine frame with sufficient clearance to rotate freely, yet not encounter interference with the frame (the functional map is the Tolerance-Map that would represent the allowable variations of surfaces where the bearings are seated). As such, a functional map models what a designer wants to achieve (e.g., the maximum degree of variation that will not deteriorate the desired function of a device: for example, the clearance between a shaft and bearing to get smooth operation). An accumulation map models the range of variation the designer will obtain if the designer uses his current dimensioning and tolerancing scheme and values. Therefore, the accumulation map must fit inside the functional map, indicating that the geometric variations that could occur are within levels acceptable to the designer.

Further, Claim 1 has been amended to further clarify that a geometric form is represented by a Tolerance Map. As such, it is respectfully submitted that rejection of Claims 1-12, 16-19 and 21-23 should be withdrawn because the claims are definite on their own, and further in light of their definitions in the specification as summarized hereinabove.

Claim Rejections Under 35 U.S.C. 102(b)

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Rejection of Claim under 35 USC 102(b) as being anticipated by Iannuzzi is respectfully traversed because Iannuzzi does not disclose all of the claimed limitations.

Iannuzzi does not disclose a method of evaluating tolerances of computer assisted designs for the manufacture of objects comprising:

"representing each tolerance zone for each geometric feature of said object by a model with an algebraic form and a geometric form, wherein the geometric form is represented as a Tolerance Map stored in a computer," as required by Claim 1.

Iannuzzi is directed to a method of storing and organizing pieces of information relevant to GD&T (Geometric Dimensioning and Tolerancing). Using Table Lookup and Rules Iannuzzi provides a procedure to validate only certain aspects of completeness and correctness (col. 4, lines 18-27; col. 8, lines 42-46). An analogy to this is in computer programming, where a parser validates the presence of all the required parameters for each function call in a computer program. For example, in a computer program that includes a function call PRINNT(file name, printer name) for printing contents of a file, the PRINT function requires two parameters: (1) the name of the file to be printed, and (2) the name of a printer for printing that file. A parser ensures that both parameters are provided for the PRINT function in a computer program that is input to the parser. That is the function of parser. Similarly, Iannuzzi provides a procedure

to validate only certain aspects of completeness and correctness of a tolerance plan. Iannuzzi does not provide tolerance analysis which is the problem addressed by the present invention. Iannuzzi simply determines if a tolerance plan as defined by input datum is complete and well formed. Iannuzzi does not disclose tolerance analysis. That is Iannuzzi does not consider the issue of accumulation at all. Iannuzzi looks only at tolerance specification, not how the errors "stack up" or accumulate as parts are put together. An example analogy is spell checking and grammar, wherein rules of the language are followed, but there is no evaluation of the quality of the content of a given piece of text.

As noted above, tolerance analysis involves the accumulation of error when imperfect parts are put together (i.e., stackup problem). Iannuzzi does not in any way deal with tolerance analysis and the accumulation problem as does the present invention. By contrast, Iannuzzi specifically states:

> "An apparatus and method provides for the input of geometric data representing features of a manufactured part and data representing datums and tolerances for the features. Relationships are established between the data and degrees of freedom are determined for the part features and tolerances. **The relationships and degrees of freedom are interpreted to determine if the tolerance plan defined by a designer is complete and well formed. If not, the designer may then revise the tolerancing plan to provide for a more consistent and useful tolerancing plan** resulting in higher quality, lower cost manufactured parts and assemblies." (Abstract, emphasis added).

Iannuzzi simply determines if a tolerance plan as defined by input datum is complete and well formed. Iannuzzi does not disclose tolerance analysis. However, according to the present invention, Tolerance Maps for objects are

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provided, wherein a primary function of the Tolerance Maps is to determine accumulation of error in the stackup. Iannuzzi only determines if a tolerance plan as defined by input datum is complete and well formed. Iannuzzi does not disclose tolerance analysis steps at all, nor does Iannuzzi disclose tolerance analysis using Tolerance Maps by:

"computing in said computer interdependencies between said stored maps and interdependencies between submaps of said stored maps to determine how different tolerance zones for said geometric feature affect each other and to determine how different tolerance zones for different geometric features of said object affect each other," as required by Claim 1.

For example, using the above steps according to the present invention, given two imperfect parts, each part is analyzed and a corresponding Tolerance Map is created that indicates all of the potential imperfections that are tolerated by the design specification. Then, when the two parts are put together, their Tolerance Maps are combined/transposed (e.g., using the Minkowski sum) to generate a new Tolerance Map (i.e., the accumulation Tolerance Map) which is the accumulation of the tolerances and imperfections of the two parts.

The accumulated errors can be used to allocate tolerances for the parts within a certain specification by optimization. Further, Iannuzzi does not disclose a mathematical method (for instance, minimizing unused volume) as a means to optimize allocation of tolerances by:

"selecting tolerance conditions for said object to optimize allocation of tolerances to each of said geometric features of said object," as required by Claim 1.

Optimizing amounts to selecting tolerances so that unused volume is minimized between two Tolerance-Maps, one inscribed in the other.

Further, in contrast to lannuzzi, according to the claimed invention tolerances can be evaluated on a computer by quantitative analysis using Tolerance Maps, wherein the size and shape of tolerance zones resulting from stackup or accumulation of variations in the Tolerance Maps are considered. lannuzzi does not disclose accumulation of tolerances in stackup, i.e. there is no method provided on how tolerances in a dimension loop accumulate. lannuzzi does not consider tolerance zones at all (neither the shape nor size). lannuzzi does not disclose any quantitative analysis of the effect of different tolerances on the size, shape and juxtaposition of tolerance zones resulting from several tolerances applied to the same feature. And, lannuzzi has absolutely no overlap with either the application or the techniques used for our creating local models according to the present invention.

In the Office Action, the Examiner states that the claimed limitation of "representing each tolerance zone for each geometric feature of said object by a model with an algebraic form and a geometric form as a tolerance map" (Claim 1) is disclosed by lannuzzi at abstract "input of geometric data representing features

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of a manufactured part and data representing datums and tolerances for features". Applicant respectfully traverses this interpretation of lannuzzi. As discussed, the passage in lannuzzi seems to refer to the input to a program. The input to a program according to the method of the present invention, as well as lannuzzi, is the same – i.e. the geometric data, dimensions, tolerances, datums. The input only specifies the part or assembly definition. Rather, the present invention provides a computational process and type of output that is patentably distinct from lannuzzi.

The Examiner states that "computing...interdependencies between said stored maps and interdependencies between submaps of said stored maps to determine how different tolerance zones for said geometric feature affect each other and to determine how different tolerance zones for different geometric features of said object affect each other" (claim 1) is disclosed by lannuzzi at abstract "Relationships are established between the data and degrees of freedom are determined for the part features and tolerances". Applicant respectfully traverses this interpretation of lannuzzi. As noted, lannuzzi does not utilize tolerance zones or maps. Neither is lannuzzi concerned with how errors due to imperfections accumulate. lannuzzi only verifies the type of tolerance and datums. lannuzzi does nothing with the amount of the tolerance, and does not combine this amount with other amounts. Degree of freedom is quite distinct from tolerance value. lannuzzi simply stores the values wherein all the analysis is

based on DoFs not tolerance values (e.g., zone sizes or shapes) as claimed
herein.

The Examiner further states that "selecting tolerance conditions for said
object to optimize allocation of tolerances to each of said geometric features of
said object" (Claim 1) is disclosed by Iannuzzi at abstract "determine if the
tolerance plan defined by a designer is complete and well formed. If it is not, the
designer may then revise the tolerance plan to provide for a more consistent and
useful tolerancing plan resulting in higher quality, lower cost manufactured parts
and assemblies". Applicant respectfully traverses this interpretation of Iannuzzi
because Iannuzzi does not disclose the claimed optimization step. As noted,
"complete and well formed" as required by Iannuzzi, does not teach or suggest
"optimal" as required by Claim 1. To be optimal, a design must meet more than
just the minimum requirements (complete and well formed), and essentially be
the best possible. For example, to design a structural beam to carry a fixed load
over a given span, it is desired to determine the cross section and dimensions of
the beam that allows the beam to carry the fixed load. The beam shape can be,
e.g., an I-beam, a channel, a box beam, a pipe, etc. etc. The present invention
allows determining the proper dimensions for any of these beam shapes such
that the beam will be strong enough to carry the load. As such, they are all valid
solutions to the problem, but which one of the beam shapes will be the lightest
weight (use the least material)? The search for the best beam shape from the

point of view of design objective (lowest weight) is called optimization according to the present invention as claimed.

Iannuzzi uses a Rule based (Heuristic) method to determine degrees of freedom. By contrast, according to the present invention as claimed, a mathematical formulation of the constraint relations and numerical methods for constraint solving (not symbolic manipulation of rules) are used. Symbolic methods using heuristic rules, such as Iannuzzi, cannot handle coupled constraints. Also, in validating if the proper degrees of freedom (DOF) of a feature are controlled by a datum reference frame (DRF), Iannuzzi compares the composite DOFs of the DRF to the controllable DOFs of the toleranced feature (Iannuzzi, Fig. 7, #146). Because the total DOFs of the DRF are considered at the collective level, Iannuzzi is unable to determine which DOFs are controlled by each of the composing datums of the DRF. Iannuzzi, Table II, shows no association between each datum and the particular DOFs controlled when combined with other datum. For example, Table II, line 2 shows that when a point is used as a primary datum, another point as a secondary datum, DOFs u, v are controlled, but no indication of which datum controls u and which datum controls v? There is no distinction made. The global model according to the present invention analyzes the DOFs controlled progressively, to determine not only what DOFs are controlled collectively by all datums in the DRF, but also which individual datum controls each DOF. Without this distinction, the effect of datum precedence cannot be analyzed.

Further, Iannuzzi does not provide any mechanism for controlling the same DOF by more than one DOF. This is needed when finer controls are required on certain DOFs selectively. It is referred to as tolerance refinement. An orientation tolerance refines a size tolerance; a form tolerance refines an orientation tolerance. Iannuzzi does not disclose such progressively refined controls and conditions under which they are permissible. In contrast to Iannuzzi, the global model according to the present invention accounts for these refinement relations under redundant controls. Therefore, for at least the above reasons, it is respectfully submitted that Claim1, and all claims dependent therefrom, should be allowed.

Claim Rejections Under 35 U.S.C. 103(a)

The rejection of Claim 24 under 35 U.S.C. 103(a) as being unpatenable over commercial software in view of Maxey (AutoCAD) is respectfully traversed because as discussed below, Claim 24 includes limitations not taught or suggested by the references, alone, or in combination. Maxey (AutoCAD), referenced by the Examiner, only provides specification of Dimensioning & Tolernacing scheme in Auto CAD R13. Auto CAD is a popular software package for computer-assisted drawing. The dimension lines and tolerance frames created in Auto CAD are just symbols. One can create any type of tolerance frame, valid or invalid, attach it to any type of entity, whether it makes sense or not, and specify any kind of sensible or nonsensical DRF. Auto CAD (and other

CAD systems like it) have no instrument to determine if the specified GD&T are valid (or even the drawing represents a physically realizable part). The invention in Claim 24 discloses a model that provides such an instrument. Modules E1, E2, E3 are commercial software, and modules M1, M2 are standard input modules.

AutoCAD only allows mark-up of drawings with text and symbols. There is no math model to even validate if the scheme makes sense. For example, AutoCAD allows specifying a flatness tolerance on a cylindrical surface or to specify two parallel planes as datums for setting up a coordinate system, or specify a form tolerance greater than size tolerance. None of such specifications make sense, nor are they permitted by either the ASME/ANSI Standard or the ISO Standard. The reason AutoCAD will allow such nonsense specifications is that there is no math model in AutoCAD to validate the specifications. The symbols and text are simply stored as attributes of the entities, just like the color of a line. Interpreting AutoCAD to support tolerance analysis would be similar to interpreting Adobe Illustrator, MS/Word Picture Drawing tools or MACDraw (which enable drawing lines and boxes), to support electrical circuit analysis.

Further, with respect to the Applicant "admissions" the Patent Office mentions in the Office Action in rejection Claim 24, it is respectfully submitted that three types of commercially available software are needed to implement a tolerance modeling system according to an embodiment the present invention in Claim 24. These are indicated by the designations "E1", E2", and "E3" (e.g., Fig.

18 of original specification). Many different companies market these packages which offer comparable capabilities. However, the other modules in Claim 24 are not such. Modules M3, M4, M6 and M7 in conjunction with modules E1, E2, E3, M1, M2 and optimal module M5, provide the novel features of the claimed invention. As such, it is respectfully submitted that rejection of Claim 24 be withdrawn.
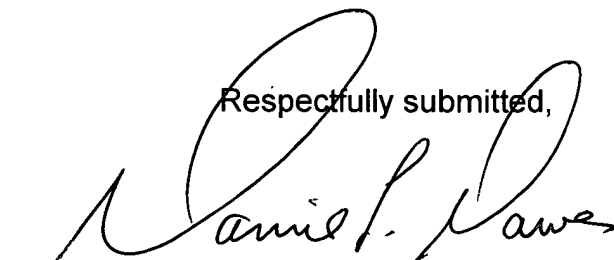
New Claims

The new Claims 25-28 are supported by the specification and drawings. For at least the above reasons, the new claims are patentably distinct from the cited references, alone or in combination. As such, the new claims should be allowed.

Conclusion

For the above reasons, and other reasons, it is respectfully submitted that rejection of the claims should be withdrawn. Reexamination, reconsideration and allowance of all claims are respectfully requested.

Respectfully submitted,

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